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BAYER LEVERKUSEN (GERMANY)

Department for Crop Protection

Development of Spider Mite Resistance to Acaricides

by G. Unterstenhöfer, Leverkusen.

(Reprinted from "Medelingen van de Rijkslandbouwhogeschool en Opzoekingstations van de Staat te Gent, XXVI, 3, 1961)

Some spider mite species have the ability to set defensive mechanisms in action and to develop strains resistant to acaricides used against them (4). For example, *Metatetranychus citri, Metatetranychus ulmi, Tetranychus urticae, Tetranychus pacificus, Tetranychus cinnabarinus* and *Tetranychus mcdanieli* are known to have become resistant to organophosphorus compounds (Parathion, Demeton, Thiometon, Phenkapton, Phosdrin etc.) and to selective acaricides (Azobenzene, Ovotran, Chlorbenzilate, 1,1-bis-[4-chlorophenyl]-2,2,2-trichloroethanol, Chlorbenside, Genite) in many areas of varying expanse. These facts weigh heavily on practical crop protection for the very reason that apart from chemical pesticides, no reliable facilities have as yet been found for minimizing the economic consequences arising out of the occurrence of spider mites which, for various reasons, continue to gain increasing prominence as major pests of crops.

With respect to the development of resistance, Tetranychidae have very much in common with Diptera for the same difficulties are encountered in controlling some species of flies and mosquitoes. But whereas the resistance of Diptera to insecticides was given full attention soon after this phenomenon became known, by intensively studying the origin and mechanism of resistance and thus proceeding along systematic lines to find new means for controlling species that had become resistant, the amount of research work carried out to study resistance to acaricides remained comparatively small for a long time although it is pleasing to note that much more is now being done in this direction. One of the main reasons for this difference in attention given to the two problems is that an experimental study of resistance to acaricides, due to the smallness of the mites, their handling and behaviour, is far more difficult than for flies and mosquitoes. But research on resistance to insecticides may also be considered as constituting valuable preliminary work for studies on resistance to acaricides.

Of the many individual questions pertaining to spider mite resistance, the origin of such resistance merits special consideration because it is the first and, as far as practical crop protection is concerned, the most important stage in the phenomenon of resistance. Valuable contributions have recently been supplied towards revealing the origin of resistance. But before reporting on these, it must be strongly emphasized that experiences gained with a certain population, irrespective of which particular question or aspect may be involved, should not be completely accepted as applying generally to all populations. For after all

each population has its own specific characteristics of resistance and mechanisms of resistance which are genetically established. For this reason, resistance to acaricides is also a phenomenon which presents itself with a wide variety of aspects. Just as in the case of resistance to insecticides, considerable proof can be furnished to show that pre-adaptation must be assumed as being responsible also for the origin of resistance to acaricides. This is generally recognised in entomology also today, in contrast to bacteriology where occasionally one also speaks of post-adaptation. Accordingly, genetically established differences of resistance are present in one population. Acaricides act as selective agents which give on-sided stimulation to the resistant genotypes. Therefore, the development of resistance is a process of selection — under the influence of an acaricide otherwise lethal to a population, the property of resistance possesses a positive selective value in that the existing resistant types, even though perhaps only with slight frequency, continue to be increasingly dominant so that eventually they alone succeed in reproducing. They ensure the preservation of the species.

In keeping with the relatively infrequent occurrence of the resistance genes, resistance is slow to increase at first but then grows rapidly. This shows that from a certain stage of selection onwards a concentration of resistance factors takes place which proceeds in the form of an exponential curve so that accordingly it becomes necessary to raise the lethal dosages in geometrical progression.

Development of resistance may be governed in its course by several factors. As far as the active ingredient is concerned, the question whether the development of resistance is a characteristic specific to the active ingredient, i. e. that some species are easily able to develop resistance to certain acaricides but have difficulty in developing resistance to other active materials, must still be left open. Gasser (4), in his experiments on selection, found that *T. urticae* developed resistance at an equal rate to the tested compounds (Parathion, Diazinon, Pyrazoxon, Phenkapton, Chlorbenzilate). In the author's own experiments, however, it was established that the rate at which resistance was developed varied for certain organophosphorus compounds.

Apart from the active ingredient and the genetic heterogeneity of a population, the intensity of selection has great bearing on the speed at which resistance develops. Generally speaking, the greater the intensity of selection, i. e. the higher the percentage of mortality in a population following application of poison, the faster resistance will develop. The attainable degree of resistance is, however, independent of the intensity of selection. Both high and low intensities of selection eventually lead to the same level of resistance, this being proved by Watson (13).

Saba (10) obtained very interesting results in his studies on the origin of resistance in *T. urticae* under the influence of TEPP in relation to the following host plant species: bean *(Phaseolus vulgaris)*, hop *(Humulus lupulus)*, plum *(Prunus domestica)*, carnation *(Dianthus caryophyllus)* and dead-nettle *(Lamium album)*. Development of resistance was followed over twelve generations, and provided the following picture:

Bean *(Phaseolus vulgaris)*	0·0023 %	→	0·011 %
Carnation *(Dianthus caryophyllus)*	0·0032 %	→	0·02 %
Plum *(Prunus domestica)*	0·0029 %	→	0·035 %
Dead-nettle *(Lamium album)*	0·0027 %	→	0·145 %
Hop *(Humulus lupulus)*	0·0032 %	→	0·73 %

The findings show that the plant host is of great importance to the development of resistance. Based on the LD_{50} value of the *Phaseolus* strain, the degree of resistance on hop was 66 times greater, on dead-nettle 16 times greater, on yellow plum 3 times greater and on carnation 2 times greater. Progress of resistance, decrease of resistance and renewed increase of resistance following a drop in the degree of resistance were also dependent upon the host plants.

Just as for insects, the problem of cross-resistance also exists for spider mites; cross-resistance is understood to mean that resistance to one particular acaricide may induce pre-disposition for accelerated development of resistance to other acaricides. As the genetic fundamentals are not the same for all populations, it is understandable that there are considerable differences of opinion when it comes to answering the question how and to what extent one active material induces resistance to other acaricides. It is generally agreed that a wide spectrum of selection exists for organophosphorus compounds. Considerable proof is available to show that resistance to one acaricidally effective phosphorus compound also means resistance to other phosphoric esters not yet used for controlling the mites. For example, the phosphorus-resistant mites (*T. urticae*) collected in greenhouses by Helle (7) were found to be also very highly resistant to Phosdrin, Thiometon and Phenkapton even though these active materials had not yet been applied as products for combatting mites. The Demeton-resistant strain of *Panonychus citri* studied by Jeppson, Jesser and Complin (8) also proved to be resistant to fourteen other organic phosphates although there were appreciable differences between the resistant (r) mites and the normally susceptible (n) mites in their response to the various active materials. We are able to confirm this finding on the grounds of extensive studies — the phenomenon of group resistance does exist for phosphorus compounds although with marked differences among the various acaricides. Further proof of this is furnished by Hansen (6) in a study specially devoted to this question. The fact that this group resistance is nevertheless not always immediately recognized in the field is because the first stages in the development of resistance may be easily overlooked due to the high concentrations that are used. It is only by determining the lethal dosage that it will then be possible to state definitely whether resistance is present.

Varying answers are supplied to the question whether and to what extent organophosphorus compounds also induce resistance to non-phosphorus compounds. Hansen (6) says they do induce resistance to Chlorbenzilate, Aramite and 1,1-bis-(4-chlorophenyl)-2,2,2-trichloroethanol. Watson (13) made a similar finding. On the other hand, Helle (7) found that the phosphorus-resistant strains which he studied were not resistant to 1,1-bis-(4-chlorophenyl)-2,2,2-trichloroethanol and Chlorbenzilate. Also in studies carried out by the author, phosphorus-resistant strains showed no resistance to 1,1-bis-(4-chlorophenyl)-2,2,2-trichloroethanol and ERADEX®. Therefore, cross-resistance can at least occur if not always. The significance of cross-resistance is that it largely determines the service life of new active materials. It also greatly limits the value of the rotational use of active materials in a programme of acaricidal treatments, at all events when resistance has already started to develop.

In view of the facts already known about the development of resistance, and outlined above, the question naturally arises why a species is not resistant

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ERADEX = quinoxaline-2,3-trithiocarbonate.

to acaricides from the very outset when it is already endowed with the ability to be resistant. Apparently the resistant members of a population must be at a disadvantage compared with the non-resistant members considering that they occur so seldom, which in fact is actually the case. It can be taken as certain that the characteristic of resistance is of negative value for a population with regard to selection when the population does not have to face controls with acaricides. For the acquisition of resistance fundamentally makes itself felt to a population in the sense of a general lowering of vitality. This correlation between resistance and vitality is also known in the case of Diptera. Consideration of this factor within the presentation of the subject under discussion is necessary because it determines the degree of attainable resistance as the end point in the development of resistance.

The question of a lowering of spider mite vitality that accompanies increase of resistance has been fully investigated by Dittrich (2). In his studies he used an n-strain and an r-strain. The r-strain was developed from the n-strain during tests on acaricides lasting eighteen months, by carrying out 22 treatments with increasing concentrations of Demeton, starting at 0·005 % and finishing at 0·2 %. A comparison of these populations revealed

1. that there is a close relationship between the degree of resistance and egg-laying in the sense that as resistance increases the number of eggs laid decreases, in fact all the more so the higher are the prevailing temperatures — the lower production of eggs was also reflected in a reduction of voracity;
2. that at high temperatures far fewer r-mites than n-mites are capable of completing the cycle of development from egg to adult. — n-mites survived extreme temperatures which r-mites could not tolerate;
3. that r-mites were more sensitive than n-mites to deprivation of food;
4. that the sex ratio in r-strains is in favour of males, and in n-strains it is in favour of females.

Increasing resistance, therefore, lowers vitality; this reduction of vitality is all the greater the heavier the burden on the organism due to high temperature and high relative humidity. When the property of resistance prevails under the influence of an acaricide despite the reduction of vitality, then it is because it protects the population from extinction.

On account of the losses of vitality, limits are, however, also set to the attainable degree of resistance. In some cases these limits are narrow and in other cases they are wide apart according to the prevailing environmental conditions. For this reason, the development of super-resistant homozygosis may be considered as practically impossible. This is substantiated by the firm observations that maximum resistance is attained by heterozygotes, whereas the homozygotes are eliminated by natural selection. Selection for resistance and selection for vitality, fecundity etc. take place simultaneously and prevent the one-sided stimulation of resistance factors which eventually prove destructive for a population.

From the described relations and conditions it is evident that resistance in nature is not unlimitedly stable. On the contrary, it recedes as soon as a population no longer has to face control by the selective acaricide. Clear proof of this, too, is provided by experimental studies and practical observations. For its part, reversion is also to be regarded as a process of selection in which the

environment favours the non-resistant, vital types which on account of their higher fecundity have an advantage over the resistant types. The reversion of resistance proceeds all the faster the greater the environmental burden brought about by high temperature and high relative humidity. But generally, resistance recedes at a slower rate than that at which it increases because throughout the intensity of selection brought about by the use of pesticides is greater than that due to environmental conditions. One should not, therefore, expect the former state of susceptibility to return within a short time of applications of an acaricide being stopped, especially as it takes some time for the resistance factors to drop again below a certain frequency.

Gasser (4) reports about a phosphate-resistant strain *(T. urticae)* that originated from carnations, which retained its resistance also after it had not been exposed to Parathion for a long time.

We made similar observations with a strain that originated from carnations. On the other hand, Saba (10) and Dittrich (2) found that resistance decreased considerably immediately after the application of acaricides had been stopped. Strains that lost their resistance quickly regained their former degree of resistance following renewed selection.

In closing it is interesting to note that according to the studies of Taylor and Smith (11), resistance is dominant and is transmitted by both sexes. This fact may be of importance regarding development of resistance in regions where the phenomenon is not yet known, in that it can be carried into such unaffected regions, for example through the exchange of goods and general traffic communications. In this respect, there is still much important work awaiting systematic research, and in fact one cannot stress too higly how essential it is for more attention than ever before to be devoted to the phenomenon of resistance to acaricides.

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Overwintering of the Red Spider Mite *Tetranychus urticae* KOCH in Hop Gardens *(Acari, Tetranychidae)**

by K. Nuber

(Institute of Crop Protection, Agricultural University, Stuttgart-Hohenheim. Director: Prof. Dr. B. Rademacher)

It is widely known that the males of the red spider mite *Tetranychus urticae* Koch do not hibernate; they die in autumn, and only the females overwinter. The winter females differ from their summer counterparts by their colour; the former are yellowish-orange while the summer females are green and also have dark spots along the edges of the dorsum, which the winter females do not possess. The orange-coloured winter females minimize their feeding or stop it completely towards the end of the growing season, and do not lay any eggs.

1. Overwintering quarters of the red spider mite

a) On nettles

At various intervals during the winters of 1959/60 and 1960/61, dead nettle shoots which were still attached to the rootstock were collected from nettle stands growing in the vicinity of Stuttgart-Hohenheim and near to hop gardens in the region of Tettnang. The collected shoots were cut open in the laboratory and examined under a binocular for colonization of winter females. Dead

* The suggestion and encouragement of this work by Prof. Dr. G. Dosse is sincerely acknowledged. Thanks are gratefully extended to the Deutsche Forschungsgemeinschaft for their support of these studies.

nettle leaves collected from the ground were similarly examined. Samples of soil were also taken at various depths in some of the places where the shoots and leaves were collected, and likewise examined for the presence of winter females. Only few isolated mites were found on the outside of the stems while small and large colonies (up to 40 mites) were frequently present in the medullary canal of the shoot stump open at the top end.

Winter females were also often found concealed under a fine web spun in the small curvatures and folds on dried and shrivelled leaves.

Only dead mites were discovered on moist leaves which had been lying very close to the ground. In the soil samples taken between the surface and a depth of 2 centimetres, small isolated colonies of winter females were found on half-rotten pieces of leaves, but very many of those mites were dead. No winter females were found in the soil at depths of 2 to 5 cm and 5 to 8 cm.

Fig. 1: Colony of winter females on folded hop leaf (February, 1960)

b) On hops

In October and November of 1959 and 1960, leaves were sampled from dead bines in hop gardens situated in the Tettnang region and also in the experimental plot at Hohenheim; furthermore, pieces of leaves lying on the ground were collected at those sites in February and March of 1960 and 1961. The controls showed that on much of the sampled dead foliage, colonies of winter

females were hidden in folds and curvatures on the leaves. The examination of the pieces of leaves collected in February and March produced a similar finding although many of the mites found were dead, especially on those leaves which had been in direct contact with the ground and exposed to rain and snow. Above the ground, winter females were often found singly or in colonies numbering up to 300 and more on one folded leaf.

Samples of soil were taken in autumn and spring from untilled hop gardens at depths of down to 8 centimetres but no *Tetranychus urticae* were ever found in these samples. In soil samples taken from ploughed hop gardens in late autumn and winter, some winter females were found in the soil but they were always on half-rotten pieces of leaves, and it was only very seldom that any of these mites were still alive. These findings are contradictory to the results obtained by Linke (1953) according to whom the mass of *Tetranychus urticae* females migrate into the soil and overwinter there. But Linke does not state whether his findings are for tilled or untilled hop gardens. From results of the author's own studies in gardens with a light to medium-heavy loamy soil, it is assumed that the winter females do not actively enter the soil but are passively carried into the soil on leaves and pieces of leaves buried under the ground by the plough in autumn; most of these mites then die in the soil. It has frequently been observed (Zattler [1948], Linke, and Rebl [1950]) that the initial infestation in spring is greater in gardens with a sandy soil and that in these gardens spider mite damage is severe in early summer; it thus appears evident from these observations that mites buried in the ground have a greater chance of surviving in medium-heavy to light sandy soils which have good permeability to water, so that when the temperature rises in spring they are able to migrate to the young shoots of the plants.

Jary (1935) found that mites frequently spend the winter in the cracks of hop poles and in the hills; this was also observed in Tettnang.

Sections of lateral shoots on the bottom parts of the bines, which remain attached to the rootstock until the plants are pruned in spring, also provide very important winter quarters for the mites. Many of these thin lateral shoot stumps are still 3 to 10 centimetres long. Their tips are usually dead so that in autumn the winter females are able to migrate from the leaves that have fallen at harvest time, into the open medullary canal.

More than 1,000 shoot stumps were collected from various hop gardens in the Tettnang growing region and examined for colonization; of these, an average of 15 to 35 % were infested by mites. On most of the colonized shoots between 5 and 10 mites were counted, while on some there were as many as 90. According to our findings, the mites do not hibernate in the medullary canal of the main shoots. There are two recommendations for hop growers, which ensue from the above findings. Firstly, the bines should be cut off close to the ground as soon as possible after the harvest and immediately burnt. Secondly, a thorough winter ploughing should be carried out in order to bury all the leaves under the ground so that the mites will die in the soil.

Laboratory tests were carried out to examine the question whether winter females migrate into the soil. Beakers of 6 centimetre diameter were filled with compost earth, and a ring of petroleum jelly was applied to the rim of the beakers. 30 to 40 mites were placed on the earth surface in each beaker, and the beakers were then placed in thermostats where they were kept for 3 weeks at temperatures alternated every 24 hours from 10—12° C to 0—+2° C. At the end of this period, they were transferred to a refrigerator where they were

kept for 5 weeks at a temperature of 0 to +2° C. When the beakers were checked at the end of the 8-week period, some of the mites were found dead in the ring of petroleum jelly, and others were settled on the glass wall immediately above the surface of the earth. The majority of the winter females had crawled under tiny lumps of earth on the surface but none of them had penetrated deeper than 0.2 centimetre. This confirms that the spider mites do not actively migrate into the soil.

In a second test series, hop shoot stumps were split open, placed in dishes and covered by a 2—3 centimetre thick layer of sandy soil; this soil had been steam-heated beforehand for two periods of 2 hours each in order to kill all living organisms present in it. A ring of petroleum jelly was applied around the rim of the dishes which were then left to stand for 6 to 8 weeks in four different sets of conditions:

1. In dark thermostats at a constant temperature of 21° C.
2. In the laboratory at approx. 18° C.
3. In dark thermostats at a constant temperature of approx. 10° C.
4. In dark thermostats at a constant temperature of approx. 3° C.

The check showed that in cases 1 and 2 the majority of the mites had become trapped in the petroleum jelly and were dead, while only a few mites were found in the soil at the bottom of the dishes or in the shoots. Many of the mites kept in the dark thermostats at approximately 10° C remained on the shoots or in the lower layer of soil, while only a few migrated upwards where they became trapped in the barrier and died. In case 4, all the mites were still in their original hiding places. This substantiates the assumption that winter females which are passively carried into the soil, are quite capable of migrating through loose layers of dry soil at higher temperatures, thus confirming that on extremely light soils or in sandy areas there is a relation between increased spider mite infestation and the better overwintering facilities.

Causes of the development of winter females

In autumn, greenish-coloured imagines first develop from the female nymphs of the final generation (August to September). Their transformation into winter females, visible from the change of colour to yellow and the small, gradually paling dorsal spots, begins 3 to 4 days later.

Copulation also takes place during this period. It may take 3 to 4 weeks before the mites have acquired their characteristic yellowish-orange colour.

No papers have yet been published reporting on exact studies of the causes of the development of winter forms. Some authors (Reif [1949], Gasser [1951], Linke [1953]) assume that such influential factors as temperature, period of daylight and available food have bearing on the development of winter females. Linke (1953) states that the main cause is the shortening of the days, especially when the juvenile stages (larvae, nymphs) are exposed to conditions of lessening daylight. The experiment described in the next paragraph, which was carried out by the author, showed that the light factor obviously does have a decisive bearing on the development of winter females.

Two groups each consisting of 15 winter females which had been exposed for 6 weeks to a temperature of + 2 to 3° C, were kept on nettles for 15 hours at 24° C in a dark thermostat and a light thermostat, respectively. The progeny was bred under the same respective conditions. Females and males developed

from all the mites in the F_1 generation, proof that copulation had taken place before the transformation into winter females. As soon as the female progeny of both groups had reached their final quiescent stage, they were all placed in a dark thermostat at a temperature of 18° C. Only summer females developed from the quiescent stages which had undergone their embryonic development in light while from those which grew in the dark thermostat only winter females developed. These results are in keeping with the findings of Linke (1953), viz. that the influence of light on the juvenile stages attaches considerable importance in this question.

Another aspect of the overall question investigated was whether only one certain embryonic stage need be exposed to unfavourable light conditions for winter females to develop. 15 to 25 mites of each of the 3 active and the 3 resting stages were kept for 10 days in dark thermostats at temperatures of 10 and 20° C. Afterwards they were raised to the adult stage in the laboratory where additional light was provided (16 hours). Egg-laying summer females developed in all cases so that these findings confirm to a certain extent the results obtained in the above experiment. In other experiments that were carried out, final quiescent stages were sampled from hop plants in mid-September; they were kept indoors where they were exposed to daylight and a temperature of approximately 18° C. They all developed into egg-laying summer females, even though at the time the resting stages had been collected the first winter forms were already present on the hop leaves.

The reaction of final quiescent stages which were collected in late September and kept under different conditions on young hop leaves in single cages, varied most considerably. (Tab. 1)

Table 1: Development of final resting stages of red spider mite to summer and winter females

Experiment started on Sept. 26		Check on Oct. 26		
No. of quiescent stages	Temperature and light conditions	No. of winter females	No. of summer females	No. died
30	+ 18° C in dark thermostat	30	—	—
30	+ 5° C in dark thermostat	21	5	4
30	+ 18° C in light for 16 hrs.	2	25	3

It is evident from the results of these experiments that when the mites enter the final quiescent stage it is still not certain whether they will develop into summer or winter forms. Consequently the shortening of the period of daylight during the juvenile stages in autumn apparently does not have the effect of already finally determining in those stages which form they will eventually assume. The development of winter females can be prevented by the influence of light while darkness and high temperatures or darkness and low temperatures have just the opposite effect.

At the same time as the above experiments were in progress, a parallel series was carried out in which final quiescent stages were kept on leaves of

Table 2: Influence of different food on the development of summer and winter females of red spider mite.

No. of quiescent stages	Food	Check on Oct. 21		
		No. of summer females	No. of winter females	No. died
18	Young hop leaves	13	4	1
17	Old hop leaves	7	8	2
20	Young nettle leaves	14	5	1
20	Old nettle leaves	12	4	4
20	Young bean leaves	15	3	2
16	Old bean leaves	13	2	1

various host plants (different food) in single cages at room temperatures of 18 ° C and in additional light (16 hours). The results are given in Table 2.

These results of the above experiment suggest that the offered food (host plant) also has a certain influence on whether the mites develop into summer or winter females. The tendency for summer females to develop is greater on young leaves, at least on those of hop plants.

An experiment in which groups of 30 larvae were raised on young and old leaves of hop and bean plants in the laboratory in additional light (16 hours) led to the development of summer females in all cases. Approximately 80 % of the larvae fed on young leaves were raised to adults while very many of the larvae fed on old leaves died and only about 30 % of them reached the adult stage. It can be concluded from this finding that unfavourable food conditions (old leaves) during the juvenile stages are not to be considered as constituting the sole factor responsible for initiating development of winter females.

An experiment in which red spider mites were transferred from hops to hops and beans in the greenhouse showed that low temperatures or, as Gasser (1951) believes, physiologically old leaves are not responsible for the development of winter females. In both cases, winter and summer females occurred together from mid-October to mid-April even though young plants were added every 2 to 3 weeks and the temperature ranged from 12 to 22 ° C (mean of approx. 17 ° C). Winter females, therefore, developed also on young leaves in conditions where the temperature was not low, although there was no additional light.

It can be assumed from the results of all the experiments that the light factor (shortened period of daylight) is evidently the main cause for the red spider mite's predisposition to develop into winter females.

Causes of transformation of winter females to summer females

The orange-coloured winter females enter into a certain state of rigidity in their winter quarters. When they are taken indoors they begin to move after about 10 to 20 minutes. We attempted to break the winter dormancy and to induce the mites to lay eggs. It was observed that the females begin sucking

intensively, which is clearly evident from the green colouring of the body. The dark spots on the dorsal sides also reappear although a more or less orange-green to yellow-greenish tint remains for some length of time. But the mites already start to lay eggs in this stage of colour-changing. A complete change of colour to the green of the summer females may take up to fortnight.

Winter females were collected from their winter quarters in October and February, and placed in single cages where they were kept on fresh leaves under varying conditions (Table 3).

Table 3: Start of egg-laying after breaking the winter dormancy (females collected in October).

No. of mites	Pre-treatment	Transformation conditions	Average duration until start of egg-laying, expressed in days
20	—	Room temp. approx. 18° C, daylight	40
10	—	Dark thermostat 18° C	39
15	—	Dark thermostat 24° C	35
30	30 dys. at + 10 to 12° C in dark thermostat	Room temp. approx. 18° C, daylight	19
18	30 dys. at + 5° C in dark thermostat	Room temp. approx. 18° C, daylight	17
23	30 dys. at + 5° C in dark thermostat	Thermostat at 18 to 20° C 16 hrs. of light	15
13	60 dys. at + 5° C in dark thermostat	Thermostat at 18 to 20° C 16 hrs. of light	11

It was found that for the mites collected in October the time that elapsed until the lst. egg-laying, when they were kept at room temperature and exposed to daylight, amounted on the average to 40 days, and when they were kept in a dark thermostat the duration until egg-laying started was about the same. Exposure to high temperatures resulted in a shortening of the period before egg-laying started. But when the mites were exposed to lower temperatures for

a time, they began to lay eggs earlier. The duration until egg-laying started in this case is inversely proportional to the influence of low temperatures. Another experiment in which the winter females were not collected from their hiding places until late February produced the results given below in Table 4.

Table 4: Start of egg-laying after breaking the winter dormancy (females collected in February)

No. of mites	Pre-treatment	Transformation conditions	Average duration until start of egg-laying expressed in days
15	—	Room temp. 18° C, daylight	9
15	—	Dark thermostat 24° C	6
14	20 dys. at + 5° C in dark thermostat	Room temp. 18° C, daylight	8
20	40 dys. at + 5° C in dark thermostat	Room temp. 18° C, daylight	8

It is evident from the above results that winter females which have survived cold temperatures in the field have a disposition to transform as quickly as possible into egg-laying summer females. In contrast to the mites collected in October, those collected in February were found to undergo transformation in a very much shorter time. The pre-treatment at relatively low temperatures had no influence on these latter mites. One may, therefore, rightly assume that when the weather conditions are warm and the plants start to shoot early in spring, the overwintering females will very quickly begin to lay eggs, resulting in a speedy build-up of the spider mite population.

The number of eggs laid by such transformed females and the length of time these females live are, however, factors that have great bearing on the eventual population density so that they were investigated in single-cage experiments carried out with winter females collected in March. 48 mites were kept in thermostats at a temperature of approximately 20° C and exposed to light for periods of 16 hours. It was found that on the average they lived for 23 days and each laid an average of 96 eggs. In a dark thermostat, 54 mites had an average life of 27 days and each laid an average of 76 eggs during that period. In both cases, the mites started to lay eggs after 4 to 5 days, and their change of colour to green summer females was completed within about 10 days. The figures for length of life and the average number of eggs laid largely agree for the two cases so that one must assume that for mites which have been exposed to and have survived cold temperatures, the degree of heat is the only factor that initiates transformation provided the mites have a supply of suitable food. The length of life following transformation into the summer

form and also the recorded number of eggs laid per female are within the limits of variation that apply to data determined for females of a summer generation. In a comparison experiment, a number of winter females were taken out of the greenhouse from the earlier mentioned breeds, and kept under the same conditions on fresh leaves in single cages. In the light thermostat, all 40 mites of this particular group started to lay eggs after about 20 days; they lived for 28 days, and each laid an average of 35 eggs. Out of the 36 mites placed in the dark thermostat, 24 began laying eggs after about 32 days, while the other 12 had still not laid any eggs after 8 weeks. The 24 mites laid an average of 52 eggs each, and lived for an average of 52 days. These results again confirmed that winter females which had never been exposed to low temperatures must be kept for a very long period in favourable conditions before they start to lay eggs. On the other hand, it must be assumed from these experiments that not only temperature but light, too, has considerable influence on the transformation of winter forms to egg-laying females.

Discussion and summary of results

Dead shoots and pieces of leaves appear to be the main winter quarters of red spider mite on nettles and hops. It is considered unlikely that the mites actively migrate into the soil. From the results of the studies it appears that a recommended practice would be to cut off the hop bines close to the ground in autumn so that the mites which have migrated into the shoot stumps will also be destroyed when the bines are burnt. The soil should be thoroughly ploughed in autumn in order to bury as many withered leaves as possible under the ground. Consequently, mites that have settled on those leaves will die underground during the winter. According to the results of the author's own studies, unfavourable light conditions are chiefly responsible for the development of winter females in autumn. The influence of low temperatures on winter females has the effect of accelerating their transformation into egg-laying summer forms in spring when the weather becomes warmer. As a result, a speedier build-up of the red spider mite population becomes possible. An extremely thorough control of red spider mite should be carried out on young, shooting hop plants up to 1 metre height of growth. This will greatly decimate the early colonies and thus prevent build-up of a population density which could otherwise lead to crop damage in summer.

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The coffee rust in Kivu, description and control

by E. van de Walle

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Introduction

In practically every country in the world where it is cultivated the *arabica* coffee tree is affected by this important fungus called *Hemileia vastatrix* Berkeley et Brome. In Africa it is the most feared and widely spread disease. In the past it contributed to eliminate coffee farming from Ceylon and today it seriously threatens the Central and South American continent. It may even be foresaid that it will reach that continent sooner or later in spite of the strict quarantine measures taken by the countries there.

On the other hand, in the regions already affected it is often the limiting factor of the profitableness of coffee plantations. We therefore find it very suitable at this time to study this disease and the possibilities of control.

I. The pathogen

1. Description

The fungus is closely related to the wheat rust and can be classified as follows: Basidiomycetes, Phragmobasidiomycetes, Uredinales, Pucciniaceae, *Hemileia vastatrix* Berk. et Br. It has therefore a septate mycelium and two generations, the first one is sexual and called gametophytic, the other assexual or sporophytic.

The fungus is an obligate endophytic parasite of a very specialized nature. Like other rusts it is heteroecious although the alternate host on which the intermediate fructifications should appear is not yet known (1).

The role of this alternate host is in any case unimportant since the infected coffee trees produce uredospores throughout the year.

The uredospores are normally responsible for the infection. They germinate by producing one or more germ tubes which are, however, not capable of penetrating the epidermis directly. These tubes ramify on the leaf surface until they meet a stomata. Once that is found, an appressorium (2) is formed and the mycelium proceeds through the ostiole producing a ramification of hyphae mainly located in the lacunose parenchym. From there on they are able to penetrate more or less deeply into the palissadic tissues depending on the sensitivity of the hosts (1).

The mycelium develops intercellularly and penetrates the cells by means of "haustoria" or suction organs.

The mycelium then thickens in the nearby substomata chambers and forms a stroma from which the sterigmata carrying the uredospores develop (2). These fructifications appear only at the stomata openings.

The uredospores are slightly reniform and triangular in structure. They are characterised by their orange colour and are covered with small asperities except for the concave side which remains smooth. These spores are able to infect an new leaf directly and so doing they close the sporophytic cycle. The teleutospores appear later but on the same fructifications. They are top-shaped and smooth (2).

When it germinates, the teleutospore forms a relatively long promycelium which is transversely septated and produces four spherical basidiospores.

Up to now the alternate host on which the gametophytic generation is completed has not been found but it has been established that it is not on the coffee plant.

2. Factors affecting spore germination

The influence of different factors on the germination of the uredospores has been studied by many authors and has been commented in various, often contradictory ways.

a) *Water and humidity*

Mayne reports that germination cannot take place unless water is present and many authors (2, 3) are of the same opinion.

Burch indicates more precisely that an aerated water drop is necessary for germination, while Marshall Ward states that the spores must have the opportunity to take up a sufficient amount of water and air before they can germinate.

Finally von Faber expresses a similar but clearer opinion by saying that in order to germinate, the spore needs a drop of water which must be submitted to slow evaporation. Our own observations in Kivu have led us to make a clear distinction between the conditions necessary for spore germination depending on whether germination occurred during the rainy or the dry season. The high humidity prevailing during the rainy season has made it possible to obtain good germinations in vitro and in vivo even when water was not available to the spores, while germination was poor when the spore suspension was placed in a water-saturated athmosphere. It may therefore be expected that an infection will take place whenever the humidity of the air is sufficiently high if the other factors are favourable. We have also been able to ascertain this by succeeding in making artificial infections in the fields during the rainy season. For this purpose dry spores were applied to the dry underside of the leaves. They germinated normally. The lack of a hygrograph made it impossible to determine the minimum relative humidity required for spore germination.

The position is totally different during the dry season when water is definitely necessary. This water must, however, as stated by von Faber, be allowed to evaporate. In fact this condition is fulfilled in the Kivu. Indeed at the altitudes between 1,300 and 1,800 m the atmosphere is very dry during the day but at night the sharp drop in temperature brings about a heavy water condensation on the leaves which is evidenced by a heavy dew.

This dew persists on the leaves for many hours after sun-rise while it slowly evaporates thus fulfilling the above-mentioned condition. This point was ascertained in vitro by placing spores in water during the dry season and thereafter allowing the water to evaporate; germination was obtained.

It may then be concluded that while the germination requirements as to humidity are fulfilled during the whole of the rainy season, an infection may also take place during the dry season inasmuch as the other factors are favourable.

It will therefore be very difficult if not impossible to establish a warning system such as already exists for European cultures, which is based on the observations of meteorological conditions and informs the farmers of the right time to spray.

b) *Light*

Burch states that spores cannot germinate if they are exposed to light, while von Faber indicates that only the ultra-violet rays are responsible for preventing spore germination. (This, together with other factors, might also be an explanation for less frequent occurrence of the disease at high altitudes).

In Kenya it was found that exposure to sunlight kills the spores in 48 hours and that germination is better achieved in the shade. On the other hand von Faber states that a brief exposure to light accelerates germination.

In fact if we are correct in thinking that infection occurs through the underside of the leaf and since sporulation is also confined to that side, there are but few chances that the spores will be sufficiently exposed to sunlight so as to take a mortal dose before germination can occur.

c) *Length of spore viability*

The authors generally agree upon the fact that the germinative capacity can extend to a number of weeks (up to 4 weeks), but Roger (1) adds that it is longer during the dry season than during the rainy season.

In any case if it is admitted that sporulation can last for two to three months it can be deduced that the disease will easily subsist through the periods which are unfavourable for spore germination. In this way the disease extends from one year to the next in the same plantation. This fact has been confirmed as we found sporulating leaves on the trees right through the year with a minimum at the beginning of the rainy season.

d) *Length of germinating period*

This period varies greatly depending on a number of factors such as humidity, luminosity and aeration but it seems that it is mostly correlated with the temperature.

Rayner (2) while working on *arabica* found that it took $2^1/_2$ to $4^1/_4$ hours at 20 to 25 °C, while Saccas (3) found 4 to 6 hours at 27 °C on *canephora*. A mean value of 3 to 5 hours can be accepted for *arabica* coffee at 20 °C with a much longer period for temperatures below 20 °C.

In this connection it would be interesting to work up a table giving the time needed for spore germination at different temperatures, the other factors being favourable. Indeed it seems that it is not so much the absence of humidity during the dry season which is responsible for a decline in the incidence of *Hemileia* but rather the low night temperatures that prevail at the altitudes of 1,300 to 1,600 m. It is also observed that the virulence of the attacks increases with a decrease in altitude under 1,300 m. We attribute this observation to the higher night and dawn temperatures which make quick germination and infection possible when humidity is sufficient.

3. Length of incubation period

The time that elapses between infection and the appearance of the first fructifications partly depends on the temperature but also varies from one coffee variety to the other.

In Ceylon, Marshall Ward (4) found that the first spores appeared after 12 to 16 days; his studies were carried out on *arabica* coffee, probably at high temperatures.

Mayne (5) in Mysore found 15 to 16 days, Roger (1) one month at 19 °C, and Saccas (3) working with *canephora* coffee mentions 15 to 18 days.

In North-Kivu and at an altitude of about 1,300 m we found the first transparent disease spots 20 days after artifical inoculation, and sporulation began 8 days later.

The time needed for a germinating spore to penetrate a leaf is, however, difficult to determine, although it would be an important step forward if this could be done. The literature which is not prolific on this point mentions 2 to 3 days.

4. Way of penetration of the pathogen

It was commonly admitted until recently (1, 2, 8) that the germination tube could only penetrate the leaf through the stomata which are to be found on the underside of the leaves; this is also the case for the other Pucciniaceae.

Saccas (3), however, states that, at least on *canephora*, the infection is mainly localised to the upper side of the leaf and that the germ tube is able to

penetrate the cuticle directly, thus reaching the inner tissues even though stomata are not present. This statement is quite surprising and it would be interesting to ascertain whether an upper side leaf infection is also possible on *arabica* coffee. An accidental infection is of course possible since the total absence of stomata on the upper side of coffee leaves is not proved, and since a scratch on that side would also make an infection possible. It would, however, be surprising, had all the workers made a mistake on this point.

II. Description of the disease

1. Evolution and symptoms

As the symptoms are mostly well known to coffee farmers we do not intend to describe them lengthily. It may, however, be reminded that a single infection spot may reach two to three cm in diameter, and that the spots on a single leaf may progress in such a fashion as to cover the entire leaf before it finally falls.

At first the spots are only visible when the leaf is exposed to light. Later they start sporulating while their size continues to increase.

Sporulation then follows the expanding spot and so doing leaves a brown necrotic spot in the centre which may turn white if the parasitic fungus *Cladosporium hemileia* is present. When susceptible varieties are attacked, fructification may continue on the entire spot for a long time. As was stated by Roger (1) the size of the spots and the speed at which the tissues are killed may be considered as an indication of the susceptibility of the variety concerned. Indeed a rapid necrosis of the tissues is unfavourable for the development of the pathogen which is as we said an obligate parasite.

Fig. 1: *Arabica* coffee leaves showing various degrees of *Hemileia* attack. Leaf at top left is healthy

In some cases the tissues may die so fast that the pathogen itself starves and dies before it can develop any further. Finally a point may be reached where the host plant is so susceptible to the parasite that it paradoxically becomes resistant to attack.

2. Distribution and progresss of the disease

Although the infection will affect the young leaves more often than the older ones, these are not exempt from the disease.

The young infected leaves fall off more readily than those which are infected at a later stage. Leaf drop usually occurs one and a half to two months after infection.

The distribution of the diseased leaves on the tree varies throughout the year according to the severity of the infection at any given time. As can be seen from graph 1, the occurrence is at a maximum near the end of the long dry season. At that time infected leaves are found on all parts of the tree, only the very young leaves being free from *Hemileia*. During this long dry season a heavy leaf drop is observed, mainly restricted to the heavily infested leaves.

In Kivu the beginning of the long rainy season which follows the long dry season is characterized by daily tornadoes and violent winds reaching velocities of 60 to 100 km/hour. As a result many less infected leaves, some of them with only one spot, are brought down; these are mainly young leaves from the end of the branches which are therefore more exposed to wind.

At the same time the older leaves which are less susceptible and more protected from the wind, remain on the tree and so doing are able to maintain an infection source for the following year.

We must emphasize the significance of these tornadoes as to their influence on the development of the disease during the year.

Indeed the sudden disappearance of the diseased leaves which takes place at the end of the long dry season and the onset of the long rains might give the impression that the attack has receded, and that no control measures need to be taken before the next dry season.

In fact only the visual symptoms materialised by spotted leaves have disappeared through the action of the wind, and leaf counts made at this moment would have no significance as to the real severity of the attack.

It may also be added that the pruning of the trees, which generally takes place during the dry season, also contributes towards eliminating a number of diseased leaves.

With the onset of the long rains we come to the critical period as far as the progress of the disease is concerned. The rains bring back the necessary humidity conditions for spore germination. At the same time the coffee plants produce a great number of new susceptible leaves, while the strong winds ensure an excellent spore dissemination over great distances. These three factors are responsible for a new start of the disease, which will lead to a new build-up of the infection potential recently reduced by the heavy leaf drop.

For a while the rapidly expanding new vegetation masks the infected leaves which have remained on the trees giving the impression that the disease has receded. Indeed, at the altitudes of 1,400 to 1,600 m it takes a certain time (about a month) before the first spots appear on the newly infected leaves.

It seems therefore at first that the disease is not able to follow the rhythm of foliar development in spite of favourable conditions for the pathogen. How

ever, the disease spreads slowly but surely from leaf to leaf starting at the bottom branches and ascending higher and higher inside the tree, to infect the new leaves as they appear.

At cropping time the infection may be quite considerable but the farmers usually have other problems in mind at that moment. And so we come to the short dry season with a heavy infection which may in some cases gravely compromise the second harvest. Eventually the disease may take a sudden increase during the long dry season, leading to almost total defoliation of the trees.

Fig. 2: Young coffee tree severely affected by the disease. Note heavy defoliation, dried-up berries, vigorous gramineous growth

III. Damage caused by the disease

Economically speaking, the worst damage is a direct result of the heavy leaf drop. At the same time, when a whole crop is growing and maturing, the tree needs all its resources to supply sufficient nutrients to the cherries. If chlorophyllous assimilation is reduced because of a lack of leaves the cherries are unable to grow and ripen. They dry up and become what is currently called "mbuni" coffee, which cannot be normally depulped and is therefore classified in a unfavourable category.

In this connection it is also observed that the effort necessitated for maturation of the crop aggravates the tree's susceptibility to the disease, and it is often found that the susceptibility increases during this period. The heavy leaf drop may then occur during the harvest or at the end of it, and if the present harvest may still be good the next one will be gravely impaired.

Complete defoliation also results in so-called "die-back" which may lead to the death of the tree. Usually, however, the trees recover sooner or later depending on the gravity of the attack, but this has a negative effect on the next flowering. Du Pasquier (1) even indicates an increase of flower virescence.

It may be assumed that the "die-back" condition of the upper parts of the tree is followed by a reduction of the radicular volume which weakens the vitality and resistance of the tree to subsequent attack by the fungus. The same also applies to the foliar volume which will also be more exposed if it is unable to bring the crop to maturity. These two related factors may eventually lead to death of the tree.

It should also be remembered that even partial defoliation may seriously jeopardize the harvest. Indeed the two leaves normally present at each glomerule play an important part in the maturation process of the berries therein. If, as a consequence of *Hemileia*, the leaves of three or four succeeding glomerules on a twig are lost, the berries will dry up even though young leaves may be present at the top end of the twig.

This means that crop reduction may be quite considerable even if total defoliation does not occur.

As an indirect damage caused by *Hemileia* we may mention that the defoliation of the coffee tree brings about a stronger illumination of the undergrowth, which is favourable to weeds and particularly to grasses such as couch grass. These are of course very detrimental to coffee plants as most planters know.

IV. Factors influencing the disease outbreak

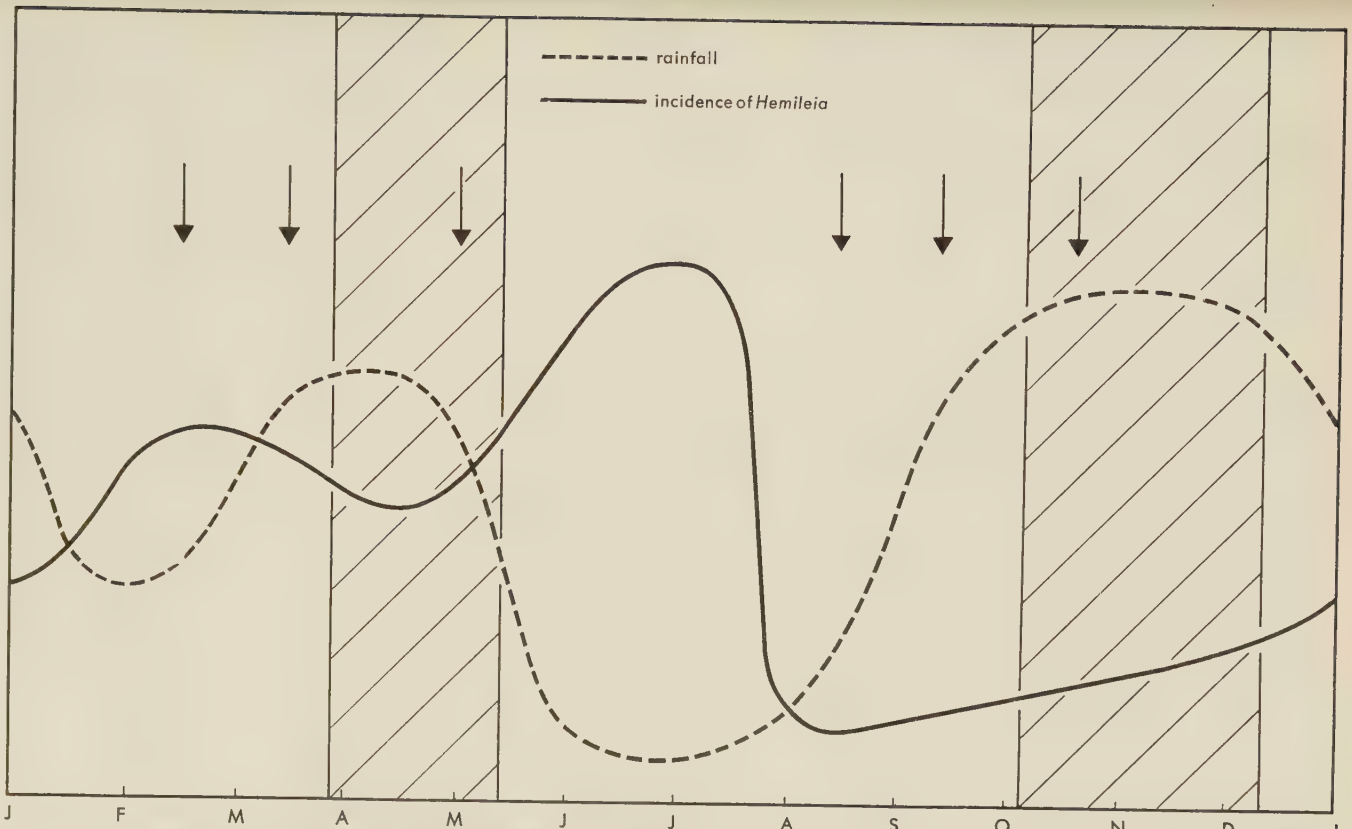
a) *Altitude*

The close interconnection which seems to exist between the intensity of the attacks and the plantations' altitude is due to the fact that the temperature, which varies with the altitude, influences the speed of the disease outbreaks.

The outbreaks are most severe at 1.200 m, this altitude being at the same time the lower limit for *arabica* cultivation. At this altitude even the night temperature stays around 20 ° C. From 1,200 m up to 1,600 m the severity of the disease decreases slowly as the altitude increases. At about 1.600 m the night temperatures are too low to ensure a good spore germination and the incidence of the disease drops further, being practically unknown above 1,900 m. This is only a general tendency of the outbreaks as local variations occur depending on the latitude and exposure of the particular plantations.

b) *Humidity*

The influence of humidity is clearly indicated if one considers graph 1. In Kivu there are two annual rainy seasons, a long one extending from September to January, and a short one from March to May. They alternate with two dry seasons, a long one from June to September and a short one



Graph 1: Relative importance and alternation of *Hemileia* incidence in relation to distribution of rainfall in North Kivu and the harvest times. Arrows indicate best treatment times. Shading indicates the harvest times.

from January to February. From graph 1 it may be seen that the curve indicating the occurrence of the disease closely alternates with that of rainfall; each rainy period being followed by a recrudescence of the outbreak. The values are obviously only relative and the graph is only meant to illustrate the incidence of the disease throughout the year as compared to the seasons. At the start of the long rains, as we said before, the infection potential is low and the disease progresses slowly until it reaches a first peak. The curve then falls as a result of the short dry season. Thanks to an increase of the spore supply the infection that takes place during the next short rainy season is much more severe, and hence brings the outbreak to a maximum at the onset of the long dry season. At the end of the dry season and together with the onset of the long rains the heavy leaf drop already described now occurs and the cycle is completed.

The bearing of the crop itself on the susceptibility of the tree should not be overlooked, either. When the crop periods are plotted in graph 1 it is found that the two maturity periods occur just before a peak of disease incidence.

Considerable climatic variations are found in north, central and south Kivu, and result in different distributions of the dry and rainy seasons, with the total crop yield being proportionately split up into two harvests. However, the alternate feature of the disease outbreaks remains the same in all cases.

c) *Age of the trees*

It was found that the young trees are rarely affected to any extent by the disease before they bear their first crop, which is normally at the age of two or three years. We have come across young plantations which were completely disease-free before the first crop, and subsequently were subjected to a heavy attack after their first crop bearing. This seems also to support the theory that heavy production increases susceptibility, as the first crop is usually a relatively heavy one. On the other hand it was observed that a plantation in a good sanitary condition, but whose production was reduced through heavy pruning, was less exposed to the disease than one which through good cultural methods was about to bring a record crop.

d) *Shading of the trees*

Apparently the shading of the trees has an indirect beneficial effect in so far as it reduces the crop yield so that the trees are far less susceptible to *Hemileia vastatrix*, while unshaded trees usually bear heavy crops which make them more susceptible to the disease.

V. Spore dissemination

This question recently brought up a controversy when two theories were forwarded on this point, respectively claiming that the wind and the rain were responsible for spore dissemination.

Up to now it was commonly admitted that spore (uredospore) dissemination was dependent on wind. The sudden outbreaks that have appeared in almost all south Asiatic countries where the disease had been unknown for years seemed to support this theory since the disease had its origin in Central Africa.

We occasionally found that some young plantations situated at considerable distances from the nearest infective focus were suddenly subjected during their third year to heavy attack. Moreover we have not come across any outbreaks that were restricted to a limited part of a plantation. However, a research worker in Kenya (6) recently published a report indicating that the spores are exclusively dispersed by rain. A little later this theory was opposed by another research worker in Tanganyika (7), who conclusively demonstrated the presence of living spores in the air by means of a simple trap. Unfortunately no mention is made as to whether the trials were made during windy periods or not. It is to be concluded that both rain and wind are responsible for spore dissemination. The violent tornadoes which occur at the onset of the rains, spread the spores over great distances such as from one plantation to the next. The wind is also most probably responsible for spreading *Hemileia* from one country to the other in spite of the strict quarantine measures that were taken at the time.

The spreading of the spores from one leaf to the other on the same tree may be achieved either mechanically when the branches are rubbed together through the action of wind, or through the action of rain drops carrying spores with them as they drip. Furthermore they may also be projected through the tapping of raindrops on the leaves. It should be remembered that tropical rain drops may be of a considerable size. In other words, this means that the tropical storms act as an ideal dissemination agent.

The question may arise as to how the spores reach the undersides of the leaves since they are only able to penetrate through this side.

The explanation is simply that most leaves of a coffee tree are not disposed horizontally but more or less vertically depending on how far they are from the centre of the tree. Therefore, the chances that a spore carried by wind or rain will land on any one side of a leaf are equal.

VI. Control methods

1. Resistant varieties

Since the first appearance of *Hemileia* in Ceylon, research workers have been looking for resistant varieties. This work is still going on intensively at a research centre specialized on this problem, under the direction of B. d'Oliveira at Oeiras near Lisbon.

The problem is not an easy one as eleven distinct strains of this rust have already been isolated (8), which differ both in their virulence and in the coffee varieties which they are able to infect. A table has been prepared in which the degree of susceptibility or resistance of each coffee variety to the different rust strains may be found (9).

This work has already furthered an interesting achievement in finding an *arabica* hybrid in Timor (10), which is resistant to 10 *Hemileia* strains.

It remains, however, to be established whether this resistance can be maintained in all the countries where *Hemileia* is present, as all the rust strains have not yet been found and it must be expected that new ones will appear in the future.

Furthermore, the productivity of these resistant varieties will have to be further tested under specific climatic and edaphic conditions. At the same time

their organoleptic qualities as well as their susceptibility to other diseases and parasites will have to be examined. Finally it will also be necessary to assess whether the varieties which have shown resistance in glass house conditions will retain this quality when exposed to a heavy crop production.

Since coffee is a perennial plant it will be a long time yet, even should the ideal resistant and productive variety be found, before it will have replaced the existing varieties in coffee plantations.

2. Cultural methods

As we mentioned earlier in this paper, it is possible to reduce the incidence of rust by increasing the shade, this resulting in a simultaneous decrease of production and susceptibility of the plant; on the other hand, an unshaded plantation will produce more, but be more exposed to the disease.

Other cultural method improvements such as good soil cultivation, organic mulch applications, weed control and judicious pruning also contribute towards increasing the vigour of the tree and hence its resistance to the disease.

3. Use of fertilizers

The mineral balance of the coffee tree is subjected to considerable fluctuations during the year, particularly at the time when the crop is maturing.

Any variation of this balance, often the result of a magnesium deficiency, increase the susceptibility of the tree to the disease.

It is also observed that a nitrogen fertilizer greatly contributes to a rapid recovery from severe attack, as it also increases the resistance of young trees.

Foliar applications of urea have led to an amazing increase of vegetative development but the results are not lasting and these applications alone cannot protect the tree against *Hemileia*.

4. Fungicides

a) *Choice of the fungicide*

Many fungicides ranging from Bordeaux mixture up to the latest antibiotics have been tried against *Hemileia*, but so far the best results have been obtained with copper fungicides.

For this reason only copper fungicides were compared in our studies such as copper oxychloride, cuprous oxide and copper hydroxide. Bordeaux mixture was not included, not because of inefficacy (it is on the contrary quite effective) but because it is not used anymore for the following reasons:

1. Difficulty and length of mixture preparation.
2. Necessity of adding surfactants and sticking agents.
3. Incompatibility with many other pesticides.
4. The high transport costs in Kivu make it too expensive.

On the other hand most copper fungicides are relatively cheap and easy to apply. A large-scale trial was started to compare the effectiveness of the above fungicides, but due to unforeseen circumstances the final observations and counts could not be made.

Fig. 3: Untreated coffee trees

However, regular observations carried out during the greatest part of the spraying period provided convincing evidence of the superiority of the activated copper hydroxide (CUPRAVIT® blue) over the two other active ingredients, when judged on its fungicidal activity and its tonic action on the trees.

Fig. 4: Coffee trees protected with CUPRAVIT blue

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The other two fungicides also controlled the disease, but further trials are needed to establish whether the difference between CUPRAVIT® blue and these other two products is significant.

b) *Timing of applications*

While the choice of the fungicide does not present any particular problem, timing of applications is a much more difficult matter due to the considerable climatic variations that have to be considered, even within restricted areas. Then again it must be remembered that the incidence of the disease is at a minimum just before the long rainy season. A fungicidal treatment at this time is absolutely necessary for the following reasons:

1. Considerable spore dissemination.
2. Favourable conditions for infection are present.
3. Vigorous development of young exposed leaves.
4. Necessity to reduce the infection potential as soon as the conditions favouring the disease are present.

Because of the rapid vegetative growth of the plant at the start of the rainy period a second application will be necessary three weeks later in order to protect the young leaves which appear continuously and are not yet covered with the spray. A third treatment should be carried out about five weeks later. The longer interval between the second and the third treatment is justified by the fact that the first two applications have left sufficient residues, and that there is a slowing down of the vegetative growth during the period preceding maturation.

These three applications should normally prevent any attack up to the short dry season which occurs in January.

A new series of three treatments at intervals of one and a half months should follow during the second rainy season so that the trees may reach the onset of the long dry season free of any attack.

This programme of treatments is meant for plantations which are heavily exposed to the disease, and it is, therefore, possible to reduce the number of treatments in areas where the incidence of the disease is less severe. It must be emphasized, however, that in this case care must be taken to apply the treatments at the right time.

It may be worth mentioning that these fungicidal treatments will also be effective against *Colletorichum coffeanum* Noack which normally occurs from October to December.

c) *Method of applications*

The continual improvement of sprayers has greatly contributed towards ameliorating the results obtained with fungicides. This is especially true where *Hemileia* is concerned for it is necessary in this case to obtain a good coverage of the underside of the leaves. The early type of knapsack sprayers equipped with hand pumps may give good results when correctly employed, but one easily gets tired and this fatigue results in lack of concentration so that the plants are not given sufficient coverage.

Furthermore these machines necessitate high volume spraying (1,000 to 1,500 l/ha, depending on the vegetative development of the trees).

For a number of years past, these hand-sprayers have been progressively replaced by light portable atomizers, in which a strong air current partly replaces water as the dispersing agent. This makes for a considerable saving of water and time.

These sprayers must, however, have a powerful air current making it possible to reach the top of the trees and to turn the leaves about so as to expose both their sides to the fungicide. Better penetration is also obtained inside the dense foliage often found when old branches bend down towards the ground (this concerns mainly multiple stem coffee trees). However, even with these perfected implements, each tree should be sprayed from at least two opposite sides, and it would even be better, although practically difficult to achieve, to treat each tree from four different directions.

The volume of water required for the atomization method may be reduced to 200 l/ha with excellent results but the dosage of fungicide per ha must of course be kept at the same level (for CUPRAVIT blue this dosage ranges from 5—10 kg/ha).

This means that any reduction in the volume of water used must be accompanied by a proportional increase of the spray concentration.

Two research workers in Kenya (11) found no significant differences between the protection obtained by spraying 1,350 l/ha or 85 l/ha. In fact they even found that the amount of copper residue on the leaves was larger in the low volume plot than in the higher volume one, which seems to indicate that a great part of the spray is lost through run-off when too much water is used.

When speaking of *Hemileia* it is usually emphasized that the trees must be sprayed in an upward direction so as to make sure that the fungicide reaches the underside of the leaves. Actually, as we said before, most leaves have a position close to vertical with the underside facing the inside of the tree. Therefore, in order to reach the underside of the leaves, the spray must be directed outwards through the foliage so that it also reaches the leaves on the opposite side. This is also a reason why powerful sprayers are preferred, which are able to penetrate the foliage.

Large size, tractor-mounted or tractor-drawn atomizers are also available, which provide fast and efficient spraying if they are driven between each row of coffee trees. They do not permit individual variations but their penetration power makes up for this disadvantage. It is obvious, however, that great care must be taken in the adjustment of the spray heads so as to obtain the desired effect.

Summary

The parasitic cryptogam is briefly described, and the factors affecting its development, favourably or unfavourably, are reviewed.

The way in which the fungus enters the leaves of the coffee tree, the evolution of the disease on the tree, and the damage caused are discussed. The main damage is the result of the heavy leaf drop.

The influence of external factors on the degree of attack and the mode of spore dissemination are also studied.

From the different control methods, it is concluded that the preventive application of copper fungicides is effective if the sprayings are judiciously timed through the year.

Two series of three sprayings are necessary. The first series must start with the onset of the long rains and the second at the beginning of the short rains. The best results were obtained with CUPRAVIT blue at a rate of 5—10 kg/ha (4·5—9 lbs./acre). The methods of application of fungicides in coffee plantations are briefly reviewed.

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Problems of Protecting Maize Crops in El Salvador

by G. Müller, San Salvador, El Salvador

El Salvador is chiefly an agricultural state which produces several important crops. The biggest proportion of the country's agricultural land is used for cultivating maize; the acreage of this crop ranges between 200,000 and 250,000 manzanas.

Together with black beans (frijoles), maize is the staple food of the people living in this small country of Central America, since it is the main ingredient for making tortillas, thin unleavened cakes. The maize harvests, however, are not always big enough to meet the needs of the population so that certain quantities which vary from one year to another, according to local yields, have to be imported, usually from neighbouring states. Besides maize, El Salvador

produces coffee, cotton, sugar cane, rice and to a lesser extent sisal, tobacco and vegetables. Livestock farming in El Salvador operates on the extensive system, except in a few cases, and does not produce enough meat to satisfy the country's needs. Coffee and cotton are the export crops, and recently growers have also started exporting sugar for the first time to the U. S. A.

The Government of El Salvador, especially the Ministry of Agriculture, spares no effort in promoting and modernizing the cultivation of maize, and has introduced the following five-point programme:

Methodical selection of the best seed
Adoption of suitable cultivation practices
Adequate use of commercial fertilizers
Education of farmers to carry out effective crop protection measures
Change-over to cultivation of hybrid maize or "improved maize varieties".

The Ministry of Agriculture's programme aims mainly at assisting and educating the small maize growers for it is in this class of agriculturists that the greatest possibilities are envisaged for bringing about an improvement. A well-organized Extension Service with advisory centres in all the major maize-growing areas, has been set up to put into execution the task which the government has set itself. Within the last three years, the Extension Service started to introduce hybrid maize, chiefly variety H 503, a Mexican development which very largely conforms to the country's requirements. This work quickly met with considerable success for today about 15 to 20 % of the maize acreage of El Salvador is already planted with hybrid maize or "improved maize". The greater yield of hybrid maize was easy to demonstrate to growers for, by adopting suitable cultivation methods and carrying out proper fertilization, yields can be realised that are about 100 to 300 % above those obtained with the usual local varieties.

Maize-growing, where it is not yet practised along modern lines, is essentially an extensive culture in El Salvador. The yield of the country's own varieties is not big enough for high production costs to be borne, so that the choice of farm management methods must be adapted to the expected yields. On the other hand, the cultivation of improved varieties and hybrid maize which will only show profitable returns provided the outlay is raised especially for fertilization and crop protection, must be carried out on intensive lines.

Intensive cultivation of hybrid maize is accompanied by an increasing number of crop protection problems for hybrid maize or improved maize is more susceptible to plant diseases and noxious insects than the local varieties raised throughout the centuries for their resistance to pests. The crop protection problems associated with the cultivation of hybrid maize can, however, be solved within the framework of economically justified crop protection measures since the resultant bigger yields more than compensate higher outlay.

Maize is planted in El Salvador once or twice a year. The first crop is sown at the beginning of the rainy season from late April to early May, and the harvest is reaped in August if there is to be a second crop, otherwise in September and October. The second crop, if planned, is sown from August to September, and is harvested from December to January or later. Due to the contrasting weather conditions that prevail in the course of the year — the rainy season beginning between late April and early May and continuing until October, followed by the dry season — incidence of plant disease and insect pest infestation differ in their severity in the two growing seasons. But despite

the seasonal fluctuations, occurrence of insect pests and diseases nevertheless persists on a relatively large scale throughout the whole year so that crop protection programmes are necessary in both growing seasons.

Insect pests attach very great economic importance in the maize-growing industry of El Salvador. The various species will be briefly discussed in the following section.

Soil insects

There are several species of soil insects that are capable of causing severe injuries especially on young plants. Their occurrence fluctuates from year to year, and also depends upon the type of soil in the various regions.

Cutworms	*Agrotis ypsilon; Feltia subterranea; Prodenia spec.*, especially *P. ornithogalli; Peridroma spec.*, an especially important pest, as well as *Copitarsia spec.* and *Lycophotia spec.*
Wireworms	*Agriotes spec.; Conoderus spec.; Melanotus spec.*
White grubs	*Phyllophaga spec.; Lachnosterna spec.*
Lesser cornstalk borer	*Elasmopalpus lignosellus* (only on sandy soils).

Fig. 1: *Agrotis* larva in cover on the ground

Whenever controls are organized against soil insects, they take the form of overall treatments usually carried out before sowing. Chlorinated hydrocarbons such as aldrin, dieldrin and chlordane are generally used.

Leaf-eating insects

This group includes a large number of major pests which are capable of completely destroying a maize plantation. The most important species is *Laphygma frugiperda* (fall armyworm), one of the family of Noctuidae, which may occur on a devastating scale especially in the rainy season (May to October).

Fig. 2: *Heliothis sp.* adult on maize

The feeding damage caused by caterpillars of *L. frugiperda* is less in the dry season but still of large economic proportions.

A second major pest is the stalk borer *Diatraea saccharalis*, better known as a pest of sugar cane, and *D. lineolata*. Total losses may result when infested plants become completely bent over during a heavy thunderstorm. It is practically impossible to control this pest in the stalk. Effective measures must be directed against the young caterpillars before they enter the stalk.

Fig. 3: *Diatraea saccharalis*, caterpillar and tunnel in maize stalk

The young caterpillars are highly susceptible to some insecticides, and can be easily controlled in the leaf axils where they remain for a time before they tunnel into the stalk. The stalk borers cause damage in both the rainy season and the dry months.

The looper *Mocis repanda* occurs in very large numbers during the rainy season, and sometimes has two generations. Unless action is taken against it, this pest is capable of completely skeletonizing maize plantations. It is easy to control with insecticides at relatively low dosages.

The extremely polyphagous salt-marsh caterpillar *Estigmene acrea* which is covered with red hairs, reproduces in very large numbers especially in years when weather conditions are favourable. Mass infestation of maize crops usually results from the fast-moving older caterpillar stages migrating into the

maize fields from adjacent stands of weeds. Maize plantations that are heavily infested with weeds are, therefore, also particularly exposed to attack by salt-marsh caterpillars; in such plantations the unwieldy moths of *E. acrea* can lay their eggs in masses on the weed plants, with skeletonization being a possible outcome of severe infestation.

The control of young caterpillars (1st. and 2nd. larval stages) is a relatively simple matter but the older caterpillar stages (4th. and 5th. larval stages) are tenacious and hence very difficult to suppress because of the thick hairy covering on their body, which makes them practically immune to contact poisoning. In fact this has been experienced even with the best contact insecticides so far marketed. The addition of soaps or wetters to the spray solution may be found helpful but this, too, has its limitations.

The maize pests listed below are of less economic importance than those mentioned above.

Fig. 4: *Estigmene acrea*, adult

The corn aphid *Aphis maidis* which chiefly builds up colonies in the shelter of leaf whorls and not so much on unfolded leaves; this pest inflicts damage on the plant by sucking out the juice, and is now also considered to be a likely virus vector on hybrid maize.

Prodenia species, chiefly *P. ornithogalli* and *P. latisfaciens*, especially injurious as soil caterpillars but also as leaf caterpillars.

Diabrotica balteata and *D. viridula*, two beetles which may cause damage by leaf-eating especially on young maize plants.

Dalbulus maidis, a leafhopper which causes considerable damage as a virus vector especially on hybrid maize (see section on diseases).

Schistocerca cancellata, a grasshopper species which occurs sporadically but when it does appear is capable of causing severe injuries. The breeding grounds of grasshoppers are usually treated with insecticides before they build up swarms; this work is done by an interstate service organized by the countries of Central America.

Fig. 5: *Heliothis zea*, worms on young maize spikes

The above-mentioned insects occur during the rainy season and, with the exception of the looper *Mocis repanda*, also in the dry season. Other very important pests that occur in the dry season are spider mites of the genus *Oligonychus*, which by sucking the juices out of the plants can cause a whole crop to become dessicated and perish within a relatively short time particularly when the mites multiply in huge numbers. Mite infestation usually starts on the older leaves close to the ground and rapidly spreads towards the growing point; well fertilized and fast-growing hybrid maize plants are apparently preferred. *Oligonychus*, a tetranychid, can be controlled easily and economi-

cally with specific acaricides. Complete mortality is obtained by carrying out two applications of METASYSTOX (i)® at an interval of 7 to 10 days using a rate of 1 litre of METASYSTOX (i) per manzana (0·7 ha) per treatment, in between 6 and 10 gallons of water (22·7 — 37·8 l) for aerial application.

Fig. 6: *Laphygma frugiperda*, worms on maize spikes

Insect pests on maize spikes and storage pests

A pest of economic importance that occurs on maturing maize spikes while they are still green and before the grains have become hard, is the corn earworm *Heliothis zea*, also known as a cotton bollworm. *Laphygma frugiperda*, the fall armyworm, may also bore into the spikes. The ratio of *Heliothis* to *Laphygma* as caterpillar pests on maturing grains of maize is about 40:60. Both insects can jointly cause reduced grain yields amounting to between 10 and 15 % on hybrid maize.

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After caterpillars have fed on the maturing grains of maize, fungi (*Nygrospora maidis, Penicillium spec., Giberella zeae)* may settle on the attacked grains and on the caterpillar faeces so that sometimes secondary damage is then caused due to the consequent rotting of single grains.

Stored grain is attacked by a number of insect pests (storage pests) such as *Tenebrio molitor* and *Calandra granaria (Sithophilus granaria)* which are usually suppressed by applying methyl bromide but only seldom (on seed) by applying insecticidal dusts.

Fungus diseases and virus diseases

In the seed bed, the small plants are chiefly infected by *Fusarium moniliforme.*

Helminthosporium turcicum is the causal organism of a leaf stripe disease which attacks local varieties and hybrid maize varieties with equal severity. Boil smut, *Ustilago maidis,* is also widespread especially on the improved and hybrid varieties.

These diseases are seldom controlled. Foliar sprayings are not carried out, and only selected and high-quality seed which is subject to approval by the Ministry of Agriculture, is treated with seed dressings. For this purpose seed dressings on a TMTD base are used. The greatest proportion of the country's acreage of maize is still sown with untreated seed.

A virus disease that has recently made its appearance is of special economic importance among the diseases of maize. Incidence of this virus disease is chiefly encountered on the improved and hybrid varieties; the local varieties are apparently only slightly susceptible to it.

Leafhoppers are the vectors of this virus disease, *Dalbulus maidis* being the main carrier. The virus is latent in weeds, especially in some grasses, which are always present in the vicinity of maize fields. Spread of the virus disease has so far been observed almost exclusively in the low-lying and warmer growing regions. No cases are known of the virus disease being carried or transmitted by seed.

The earlier the maize plant is infected, the more pronounced is the damage and losses are of greater economic proportions. Maize plants infected a few days after germination produce no grains. The symptoms of this virus disease resemble those of white tip disease on rice and a virus disease of corn known in the U. S. A. as stunt disease. The disease manifests itself as yellowish-white specks along the leaf axils; later they elongate and spread out along the leaf parallel to the mid-rib, forming streaks which may sometimes coalesce. Internodes are greatly shortened, and are only about half as long as those of healthy plants. The maize spikes remain empty, and no grains are produced. Up to six spikes are formed that are all void of grains, the rhizome and root system are excessively developed, and many small secondary roots form on the crown roots.

The incubation period of the virus in the insect is reported to be about 14 days. After a plant has been punctured and infected, it takes about 1 to 2 weeks before the first symptoms appear on young plants (up to 25 centimetres high), and approximately 4 to 6 weeks on older plants. It is, therefore, not always easy to assess the actual severity of infection in a stand.

Fig. 7: Maize plant infected by virus disease, manifested by clearly visible symptoms

Two methods are employed at present for suppressing the virus disease. They are:

Breeding of resistant varieties, and control of vectors by applying insecticides.

Insecticides and their application

In El Salvador, it was the practice in the past chiefly to use dust formulations for controlling insect pests of maize; combinations of BHC + dichlorodiphenyltrichloroethane were usually applied to suppress pest species that attack plant parts above the ground, especially *Laphygma frugiperda*. Although

the dusts gave satisfactory results, it is noticeable that growers are now changing over to the use of liquid formulations which give higher percentages of mortality and act more efficiently.

The largest proportion of maize-growing land in El Salvador is managed by small farmers whose financial resources are limited, which is the reason for some of the undermentioned methods of application being employed.

Application of dust

Bag method: Gauze bags are filled with insecticidal dust, and the insecticide is applied into the leaf whorl by tapping the bag with the hand or by shaking it. This practice has varying success especially against *Laphygma frugiperda*, and on the whole it does not produce satisfactory results because the dust often fails to penetrate through to the feeding places of the caterpillars.

Bottle method: Bottles, usually fitted with a perforated cap, are filled with insecticidal dust which is applied directly into the heart of the maize plant by shaking the bottle. This practice is more effective than the bag method for controlling *Laphygma frugiperda* because a larger quantity of dust reaches the feeding places of the caterpillars.

Mechanical equipment: The use of hand-operated dusters produces unsatisfactory results against *Laphygma frugiperda* for the simple reason that relatively little insecticidal dust drops into the heart of the maize plants. On the other hand, these dusters are most suitable for carrying out overall treatments of maize plantations, for example against infestation by the maize looper *Mocis repanda*. Aircraft or motor-powered ground machines are seldom employed for applying dusts. They are useful only for controlling leaf-eating caterpillars but not against *Laphygma frugiperda*.

Application of liquid formulations

As already mentioned, there is a widespread tendency among farmers to change over to the use of liquid formulations for controlling insect pests of maize, especially as these products have an excellent action particularly against *Laphygma frugiperda*.

Bottle method: Bottles can also be used for applying liquid insecticides in the manner described above for application of dusts, although the bottle cap must have a finer perforation so that only a few droplets of the insecticidal solution fall each time into the heart of the maize plant. The estimated rate of application for this method is 10 to 15 gallons (37·8 to 56·7 litres) of spray solution per manzana. This practice is economical and most suitable for small farmers. One labourer usually carries 8 to 12 bottles.

Knapsack sprayers: With respect to economy and the high percentage of insect pest mortality obtained with them, knapsack sprayers are superior to all other types of equipment. The amount of insecticide used per unit area is small, and therefore insecticide

costs are low as compared with other methods of applying liquid formulations. With the newer brands of insecticides that have recently appeared on the market, for example DIPTEREX®, a product which is especially suitable for controlling maize pests, the costs for knapsack sprayer applications are between 0·50 and 0·65 U. S. dollar per manzana (0·7 ha). Work with hand-operated sprayers is practical and economical even in large maize plantations. One labourer can treat an area of between 1 and 1½ manzana (0·7 — 1·05 ha) in a single work-day. The time taken for filling hand-operated sprayers with solution can be greatly reduced by setting up filling points at each end of the field and, wherever necessary, also in the middle of the field. Higher outputs are obtained with knapsack machines that do not have to be first brought to working pressure.

Tractor-mounted or trailed machines:

Tractors fitted with spray booms and high clearance machines specially developed for spraying maize crops, such as High Boys, are also extremely suitable types of equipment which enable very good results to be obtained against maize pests. But the dosages of insecticide applied per unit area have to be raised with these machines because much of the spray solution does not fall into the hearts of the maize plants and is thus lost for the insecticidal control. Higher concentrations are consequently needed to ensure that the few spray droplets which reach the pests will have sufficient insecticidal efficacy to kill the pests. The nozzles of the spray boom on tractor machines should be set at a height where they are at least 25 to 30 centimetres above the tallest plants of the

Fig. 8: Ox-drawn cart with mounted hand-operated pump; on each side are hoses fitted with lances operated by the labourers

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maize stand so that the spray jet has sufficient space in which to expand.

Aircraft: The use of aircraft is an expensive practice; aerial applications are carried out in big plantations and in cases where the conditions do not permit other methods to be employed, for example where the plants have already grown to a height of over 1½ metres or in fields that are very wet at the time.

Fig. 9: Aerial application of DIPTEREX against *Laphygma frugiperda*

The quantities of insecticide required for aerial applications are generally twice as high as those for treatment with tractor machines since very little solution is used per unit area (low volume).

Insecticides

Practically the only liquid products used in the past for controlling maize pests in El Salvador have been chlorinated hydrocarbons such as dichlorodiphenyltrichloroethane, toxaphene, aldrin, ready-for-use mixtures of dichlorodiphenyltrichloroethane and toxaphene and to a certain degree dieldrin, but only small quantities of phosphoric ester compounds. Chlorinated hydrocarbons, however, were found to have some appreciable disadvantages. In some cases they cause burns on maize plants, the required quantities of active ingredient are relatively high, and their efficacy, especially against the chief insect pest of maize, *Laphygma frugiperda,* is not always convincing.

For this reason, extensive trials have been carried out in El Salvador during the last three years to test a new phosphate of low mammalian toxicity, which has been found to possess the outstanding and all-important property of

giving excellent control of *Laphygma frugiperda*. This product is DIPTEREX (L 13/59), developed by Farbenfabriken Bayer AG in the laboratories of Dr. Gerhard Schrader. DIPTEREX has in fact proved extremely effective against most insect pests of maize in all its different formulations, as dust, granulate, wettable powder, soluble powder and emulsion. It is merely against aphids that the action of the liquid formulations is not so good. Even when applied at high dosages, DIPTEREX has not been observed to cause burns which, as already mentioned, are frequently sustained by maize plants treated with chlorinated hydrocarbons.

DIPTEREX is chiefly a stomach poison although its contact action, especially against *Laphygma frugiperda*, is also excellent. The danger of human beings and animals being poisoned by this product is very slight on account of the active ingredient's low order of mammalian toxicity.

DIPTEREX has within a very short time become firmly established in El Salvador as an insecticide in which growers and farmers know that they can

Fig. 10: *Laphygma frugiperda*; larva on maize

place their full confidence for reason of its proved wide spectrum of activity against the major pests of maize.

Laphygma frugiperda

DIPTEREX chiefly acts as a contact poison against *Laphygma frugiperda*, its action as a stomach poison being of secondary importance in controlling this particular pest. When the insecticide is carefully directed into the hearts of the maize plants, all insect stages are either moribund or dead within 15 minutes of the application having taken place, which proves what an excellent clean-up action this product possesses.

As *Laphygma frugiperda* lives in a moist atmosphere in the maize plant (rainwater and dew are retained for a long period in the leaf whorl), and since the active ingredient of DIPTEREX is readily soluble in water, the contact action is especially pronounced against this pest.

Observations carried out over a period of three years have shown that under the climatic conditions prevailing in the low-lying regions of El Salvador, the residual action of DIPTEREX lasts for no more than 5 days but it must be considered that persistence of insecticides against *Laphgyma frugiperda* is after all of limited importance because maize grows very fast, and a part of a plant which becomes detoxicated on one day is no longer the site of attack and the feeding place of *Laphygma* caterpillars a few days after the application. Re-infestation of *Laphygma frugiperda* subsequently becomes concentrated in the deeper, newly growing zones in the heart of the maize plant, which are not yet insecticidally treated.

For continued re-occurrence of *Laphygma frugiperda* to be effectively checked, several applications of DIPTEREX are necessary in one growing season. Experience accumulated in El Salvador has shown that 3 to 4 applications must be carried out on local varieties, while improved and hybrid maize varieties must be treated 4 to 6 times. A spraying programme in which DIPTEREX 80 % Soluble Powder has been chosen as an example, would therefore take the following form:

Age of maize plant in days	Dosages of DIPTEREX 80 S. P. per manzana for Hand-operated machines	Tractor machines	Aerial applications
5—10	150 g	300 g	no treatment
10—25	150 g	500 g	no treatment
25—40	200 g	500—600 g	no treatment
40—70	250 g	600—800 g	800—1500 g
70—90	300 g	no treatment	800—1500 g

Aerial applications can only be carried out with DIPTEREX 80 S. P. For ground treatments, DIPTEREX 5 % Dust or DIPTEREX 2·5 % Granular can be used instead of spray in the first three applications but liquid formulations should be applied in all later treatments.

Fig. 11: Severe *Laphygma* infestation in maize crop; foreground: untreated; background: treated with DIPTEREX

When hand-operated sprayers or bottles (see details on bottle method) are used, nearly all the spray solution falls into the leaf whorl of the maize plant. Therefore, control of insects other than *L. frugiperda* can hardly be expected from either of these two methods of application. But applications carried out with tractor-mounted and trailed machines and from aircraft are, on the other hand, effective against other maize pests besides *L. frugiperda.*

Diatraea saccharalis and *D. lineolata*

Insecticides are effective against these stalk borers only provided they are applied before the young caterpillars bore into the stalks. Usually the newly hatched caterpillars live for a few days between the leaf sheath and the maize

stalk before they bore into the stalk. This is, therefore, the best time for applying insecticides against these species. Both *Diatraea* species are highly susceptible to DIPTEREX, especially the young larvae living between the leaf sheath and the stalk. Only small quantities of a DIPTEREX solution are needed to be sure of killing these young larvae that feed on the epidermis of the leaf sheaths.

Fig. 12: *Diatraea* larva feeding in the male pollen cells of a maize plant

Hand-operated sprayers are practicable for controlling these pests although better results are obtained with tractor machines using volumes of 50 and more gallons per manzana (about 270 l/ha) and the same DIPTEREX dosages recommended in the above spraying programme for the control of *L. frugiperda*. A dosage of 500 g of DIPTEREX 80 S. P. per manzana will usually be needed. The plants must be copiously wetted with spray solution. Between three and five treatments are required according to the infestation density.

Mocis repanda

This looper species is also highly susceptible to DIPTEREX. Both liquid and dust formulations give very good control of *Mocis repanda*. For DIPTEREX 80 S. P., a dosage of approximately 250 g per manzana will be sufficient, applied in 15 to 50 gallons of water according to the type of applicator used. For DIPTEREX 5 % Dust, a dosage of 15 to 20 lbs. per manzana (6·75 to 9·0 kg) usually gives very good control.

When treating a maize plantation, all weeds present in the crop should be sprayed as well as the maize plants.

Mocis repanda reacts very quickly to a DIPTEREX treatment; the first moribund insect can be observed about 5 minutes after the application.

Estigmene acrea

Until recently, ethyl-parathion applied at dosages of at least 500 g active ingredient per manzana (with wetters added to the spray solution) was considered to be the only effective insecticide against salt-marsh caterpillars, especially for controlling the advanced caterpillar stages; the first and second larval stages can be eradicated also with other insecticides.

But it has since been found that *Estigmene acrea* can also be very effectively suppressed with DIPTEREX. The only stage not reliably controlled is the full-grown caterpillar just before it pupates. Dosages of between 500 and 1200 g of DIPTEREX 80 S. P. per manzana completely eradicate larvae of the first to fourth stages. Mortality is caused by the stomach poison action of the product; complete eradication of the population is usually achieved within 24 hours after the application.

Aphis maidis

Applications of DIPTEREX liquid formulations are usually not very effective against *Aphis maidis;* DIPTEREX dust formulations, however, can be expected to produce better results. In the conditions prevailing in El Salvador, *Aphis maidis* on maize does not present a difficult problem. Large-scale multiplication of aphids can easily be kept well in check by applying only small dosages of FOLIDOL® M Liquid (approximately 250 ccs per manzana).

Prodenia spec. (Prodenia ornithogalli, Prodenia latisfaciens)

The injury caused by *Prodenia* varies according to the stage of maize growth. *Prodenia ornithogalli* is capable of inflicting damage both as a soil caterpillar and as a leaf caterpillar while *Prodenia latisfaciens* chiefly occurs as a leaf caterpillar.

Prodenia ornithogalli is capable of causing the typical injuries of cutworms, exactly like *Agrotis* and *Feltia,* on maize plants that are just emerging. During the day, the caterpillar remains concealed in the soil, and chiefly feeds at night-time above the ground surface. Trial controls of *Prodenia ornithogalli* occurring as a soil caterpillar by applying DIPTEREX have revealed that this insect is very susceptible to DIPTEREX, but have also shown that the method of application has great bearing on the success of the control operation. Under the conditions in El Salvador, DIPTEREX 80 S. P. was only partly successful against *P. ornithogalli* when it was applied during the day by means of hand-operated equipment and tractor machines. Better results were registered when the product was applied at night after the caterpillars had emerged from their hiding places in the soil and fed on the plants. Spray solutions containing a small addition of sugar were more effective than those which contained no sugar. A very high percentage of mortality was obtained by using a dosage of 500 g of DIPTEREX 80 S. P. in 20 to 50 gallons of water per manzana, with an addition of 1 to 2 lbs. (454—908 g) of sugar or molasses, applied at night by means of tractor machines. This application also controlled *Agrotis* and *Feltia.*

The bait method has also been found to give effective control of *Prodenia* occurring as cutworms. In trial applications, maize bran was mixed with sugar, DIPTEREX 80 S. P. and some water. A mixture of the following composition is recommended for controlling *Prodenia* by the bait method:

96 lbs. (43·58 kg) of maize bran
2 lbs. (0·9 kg) of DIPTEREX 80 S. P.
2 lbs. (0·9 kg) of sugar

Approximately 10 litres of water are added to the solid ingredients, and the whole is mixed to produce a bait of a slight crumbly nature.

About 30 to 50 lbs. (13·6—22·7 kg) of this mixture are applied by hand per manzana, the actual rate depending upon the density of cutworm infestation. Bait applications, too, give simultaneous control of other cutworm species such as *Agrotis ypsilion* and *Feltia subterranea.*

Spray applications of DIPTEREX 80 S. P. at a rate of 500 g in 20 to 50 gallons of water per manzana (75·7—189·2 l) will give effective control of *Prodenia* occurring as leaf caterpillars.

In its action against the relatively resistant *Prodenia* species, DIPTEREX is superior to chlorinated hydrocarbon insecticides and the phosphoric esters previously tested. DIPTEREX acts on *Prodenia* as a stomach and contact poison. Fourth-stage larvae are moribund or dead within about 30 minutes of the DIPTEREX application. Caterpillars in an advanced stage of development that are just about to pupate react more slowly to the treatment.

Diabrotica spec. (Diabrotica balteata, D. viridula)

Diabrotica causes damage only on young maize plants; the larvae attack the stalks and the full-grown beetles feed on the leaves. Overall treatments of maize fields using DIPTEREX at the dosage recommended for suppression of *Laphygma frugiperda,* will give effective control of *Diabrotica.*

Dalbulus maidis

DIPTEREX is effective against *Dalbulus maidis,* the carrier of the new virus disease of maize, although apparently infestation cannot always be completely prevented. In particular, the action of DIPTEREX is slow against full-grown insects of *D. maidis.* Therefore, systemic insecticides are more suitable for controlling *Dalbulus maidis* as a virus vector on maize. It has, however, been found that combinations of DIPTEREX and systemic insecticides apparently produce better results than systemic insecticides applied on their own. In tests carried out by the Ministry of Agriculture (reports on these are still unpublished), at least 4 applications of METASYSTOX (i) at a concentration of 0·1 % (4 ccs of METASYSTOX (i) per gallon of water [3·785 l]) combined with DIPTEREX 80 S. P. at 0·125 % (5 g of DIPTEREX 80 S. P. per gallon of water) proved to be very effective. Timely applications are important for controlling virus vectors. In the trials conducted by the Ministry of Agriculture, the first application was carried out only a few days after the maize plants started to emerge. As a result, the large numbers of leafhoppers migrating into the maize fields from the vicinity were effectively suppressed and an early attack was prevented. Past observations have shown that at least four treatments per maize-growing season are needed.

Schistocerca cancellata

Both adults and also especially the different larval stages of *Sch. cancellata* are very quickly eradicated by DIPTEREX 80 S. P. applied at a dosage of 500 g per manzana. The population of third-stage larvae is severely decimated within about 15 minutes of a DIPTEREX treatment at the above dosage. Adult grasshoppers are killed within about 20 minutes after aerial applications of DIPTEREX 80 S. P. at 750 g per manzana.

Better results against grasshoppers are obtained, however, by using FOLIDOL M Liquid at a dosage of approximately 1 litre per manzana.

Summary

In trials carried out over a period of 3 years in maize-growing regions in El Salvador, DIPTEREX, the insecticide with the low order of toxicity, proved to be highly effective against the major insect pests of maize as well as against a number of maize pests of less economic importance.

The outstanding features of this phosphoric ester are its fast clean-up action — in this respect it is superior to the insecticides mainly used so far for protecting maize crops — which is so important especially against mass attacks of biting pest species, its good translaminar action by virtue of which DIPTEREX also effectively controls concealed pests, its excellent simultaneous action against all major maize pests, which enables farmers to give up the costly practice of using combinations of different products, and its excellent plant tolerance.

DIPTEREX is economical to use, and its application guarantees full crop yields.

Experimental Station for Cultivation of Ornamentals, Aalsmeer

Chemical Control of *Coccus hesperidum* L. (*Lecaniidae*) in Greenhouses

by W. Helle

Lecaniidae are major pests of ornamental plants grown in greenhouses. Potted plants are frequently attacked by scale insects, with the more polyphagous species such as *Coccus hesperidum* L. and *Eulecanium corni* Behé often proving to be especially injurious.

The introduction of systemic products meant the beginning of a new epoch in the control of many major pests of ornamentals, for example mites and aphids, but the success of these products against scale insects remained uncertain. From a relative viewpoint, the control of scale insects is today a problem of greater urgency than it was 20 years ago.

Following repeated trials with modern insecticides, many growers of potted plants have reverted to the use of mineral oil, a practice which, although involving some difficulties, nevertheless renders effective control possible to a certain degree.

In order to obtain a clearer indication of the prospects offered by chemical controls for suppressing these pests, a number of tests were carried out with different products.

Lecaniidae are not very suitable for tests carried out in laboratory conditions for the slow rhythm of their development must be synchronized with the

rhythm of growth of the test plants that are used. For this reason, we decided to carry out trials under greenhouse conditions.

Coccus hesperidum L. was selected as the test object in preference to *Eulecanium corni* Behé because of its faster rate of development. 20 basins, prepared for hydroponic cultivation of *Anthurium andraeanum*, were provided for the tests. Each basin contained 10 litres of standard nutrient solution in each of which 6 young Anthurium plants were growing.

The Anthurium plants were equally infected with a population of *Coccus hesperidum L.* collected in an Anthurium greenhouse at Aalsmeer. Two months after the infection, all the plants were equally colonized by all stages of this scale species. The mean greenhouse temperature recorded during the test was 22° C.

Only those insecticides were used in the trials, which are quoted in the literature for controlling *Lecaniidae*. They were applied to the plants by means of a standard type pressure sprayer. As we were also interested in establishing to what extent systemic products can be used in hydroponic cultivation of Anthurium by also mixing these products with the nutrient solution, a number of basins were filled with nutrient solution containing various concentrations of SYSTOX®.

The mortality check involves certain difficulties. A distinction must be made between adult insects which are usually firmly settled on the plants and the young migrating larvae that move about actively on the leaves. The other intermediate stages were not given consideration for practical reasons.

The evaluation was carried out with a binocular, using a magnification x 20. 12 leaves from 6 plants were sampled from each basin for the count.

The mortality rate was determined according to the formula of Abbott, taking an average of 255 larvae and 96 adults for each value. The evaluation was carried out each time 7 days after the treatment.

Another check was also made on the 21st day to establish whether there was any new build-up of the population, brought about by larvae concealed under the mother scale and thus protected against the insecticide.

1. Effect of SYSTOX in the nutrient solution

Dosages of 0·25 cc, 1 cc and 4 ccs of SYSTOX, respectively, were added to each 10 litres of nutrient solution, producing concentrations of 0·0025 %, 0·01 % and 0·04 %. The mortality figures are given in Table 1.

Table 1:

cc of SYSTOX per 10 litres of nutrient solution	Mortality of larvae	Mortality of adults
0·25	0	8
1·00	2	6
4·00	0	20

® = Registered trade mark of Farbenfabriken Bayer Aktiengesellschaft, Leverkusen.

It is difficult to account for the weak effect of this SYSTOX application especially as spider mites of the species *Tetranychus cinnabarinus* Boisd. were eradicated at the highest dosage so that it may be assumed that the plants absorbed the product.

2. Spray tests with different insecticides

In these tests 6 plants were sprayed per object; care was taken that both the lower and upper surfaces of the leaves were copiously wetted.

The dosages are given in Table 2, expressed in ppm of active substance. The liquid commercial formulations were used for all products tested. The plus (+) signs in the last column indicate whether live scale insects were present after 21 days.

Table 2:

Product	Dosage in ppm	Mortality of larvae	Mortality of adults	Check after 21 days
Phosphamidon 20 %	200	56	7	+
0,0-dimethyl-S-β-ethyl-thioethyl ester of dithio-phosphoric acid 20 %	200	51	77	+
METASYSTOX® 25 %	250	86	79	+
SYSTOX 50 %	250	39	97	+
Dimethyl-2-methoxy-carbonyl-1-methylvinyl ester of phosphoric acid 26 %	125	15	100	+
GUSATHION® 20 %	200	100	100	+
Parathion 25 %	250	27	12	+
Dichlorodiphenyl-tri-chloroethane 25 %	250	100	5	+

In view of these results, it was decided to carry out another test with GUSATHION at different dosages (Table 3).

Table 3:

Dosage of GUSATHION in ppm	Mortality of larvae in %	Mortality of adults in %	Check after 21 days
50	83	24	+
100	100	100	+
200	100	100	+
400	100	100	+

Summary

It is evident from the above results that *Coccus hesperidum* is difficult control. Disregarding the differences in the susceptibility of the various stage the larvae concealed under the scales of the mother insects are always a li potential source of new infestations. We found live larvae under dead adult which formed the nucleus for a renewed build-up of the population, all following the treatment with GUSATHION, and even at the relatively hig dosage of 400 ppm, too.

Out of the products we tested, GUSATHION gave the best effect again these scale insects. A dosage of 100 ppm killed all stages present at the tim of application. The dimethyl-2-methoxycarbonyl-1-methyl-vinyl ester of phos phoric acid also gave the same effect at higher dosages. The other products a too one-sided in their action at the usually applied dosage. Dichloro-dipheny trichloroethane, for example, only kills the larvae but is not very effecti against the firmly settled stages.

For practical applications, GUSATHION must be recommended at a dosa of 200 ppm, in other words to be used in a 0·1 % solution of the commerci formulation. To obtain 100 % mortality, the treatment must be repeated aft 2 weeks.